Banking: A Mechanism Design Approach*

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Abstract

We study banking using mechanism design, without prior assumptions about what banks are, who they are, or what they do. Given preferences, technologies, and frictions – including imperfect commitment, monitoring and collateral – we characterize incentive feasible and efficient allocations, and interpret the outcomes in terms of institutions that resemble banks. Our bankers accept deposits and make investments, and their liabilities help others in making transactions (like bank notes, checks or debit cards). This activity is essential: without it, the set of feasible allocations would be inferior. We discuss how many and which agents should be bankers. Agents who are more patient, more visible, have a bigger stake in the system, or have a lower ability to liquidate collateral for strategic reasons make better bankers, because they are less inclined to renege on obligations. Other things equal, bankers should have good investment opportunities, but it can be efficient to sacrifice return by using a bank that is more trustworthy – less inclined to renege – since this can aid in making other transactions. We compare these predictions with banking history.

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1 Introduction

The goal of this project is to study banking, without making prior assumptions about what banks are, who they are, or what they do. To this end, we adopt the approach of mechanism design. This method, in general, begins by describing an economic environment, including preferences, technologies, and certain frictions – by which we mean spatial or temporal separation, information problems, commitment issues, and so on. One then studies the set of allocations that are attainable, respecting both resource and incentive feasibility constraints. Sometimes one also describes allocations that are optimal according to particular criteria. One then looks at these allocations and tries to interpret the outcomes in terms of institutions that can be observed in actual economies. We want to see if something that looks like banking emerges out of such an exercise. To reiterate, we do not take a bank as a primitive concept. Our primitives are preferences, technologies and frictions, and we want banking to arise endogenously.

Much has been written about the virtues of mechanism design in general. Our particular approach is close to that advocated by Townsend (1987, 1990). He describes the method as asking if institutions that we see in the world, such as observed credit or insurance arrangements, can be derived from simple but internally consistent economic models, whereby internal consistency we mean that one cannot simply assume a priori that some markets are missing, contracts are incomplete, prices are sticky, etc. Of course, something that looks like missing markets or incomplete contracts may emerge, but the idea is to specify an environment explicitly and derive this as an outcome. Simple models, with minimal frictions, often do not generate

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1 For an informal description of mechanism design, following the Nobel prize going to some of its pioneers, see http://nobelprize.org/nobel_prizes/economics/laureates/2007/ecoadv07.pdf.

2 As Townsend (1988) puts it: “The competitive markets hypothesis has been viewed primarily as a postulate to help make the mapping from environments to outcomes more precise ... In the end though it should be emphasised that market structure should be endogenous to the class of general equilibrium models at hand. That is, the theory should explain why markets sometimes exist and sometimes do not, so that economic organisation falls out in the solution to the mechanism design problem.” Relatedly, speaking more directly about banking, Williamson (1987) says “what makes financial intermediation potentially worthy of study are its special functions (such as diversification,
arrangements that resemble those in actual economies; for example, they typically predict that credit and insurance work better than the institutions we observe. So, one asks, what additional complications can be introduced to bring the theory more in line with experience? We want to apply this method to banking.

Obviously some frictions are needed, since models like Arrow-Debreu have no role for banks. As has been discussed often, frictionless models have no role for any institution whose purpose is to facilitate the process of exchange. The simplest example is the institution of money, and a classic challenge in monetary economics is to ask what frictions make money essential, in the following sense: Money is said to be essential when the set of allocations that satisfy incentive and other feasibility conditions is bigger or better with money than without it.\(^3\) We study the essentiality of banks in the same sense. Just like monetary economists ought not take the role of money as given, for this issue, we cannot take banks as primitive. In our environment, the planner – or the mechanism – may choose to have some agents perform certain functions resembling salient elements of banking: they accept deposits and make investments, and their liabilities (claims on deposits) are used by others to facilitate exchange. This activity is essential, in the sense that if it were ruled out the set of feasible allocations would be inferior.

The vast literature on banks and financial intermediation is surveyed by e.g. Gorton and Winton (2002) and Freixas and Rochet (2008). Much of this research is based on informational frictions, including adverse selection, moral hazard, and costly state verification, that hinder the channeling of funds from investors to entrepreneurs. One can distinguish broadly three main strands. One approach originating with Diamond and Dybvig (1983) interprets banks as coalitions of agents providing insurance against liquidity shocks. Another approach pioneered by Leland and Pyle (1977) and developed by Boyd and Prescott (1986) interprets bank as coalitions sharing information processing, and asset transformation). We cannot expect to generate these special activities or derive many useful implications if our approach does not build on the economic features that cause financial intermediaries to arise in the first place.”

\(^3\)This notion of essentiality in monetary economics is usually attributed to Frank Hahn; for recent discussions, see Wallace (2001, 2008).
mation in ways that induce agents to truthfully reveal the quality of investments. A third approach based on Diamond (1984) interprets banks as delegated monitors taking advantage of returns to scale. These papers provide many useful insights. We think we have something different to offer, which complements existing models, but also helps shed new light on several issues, perhaps especially when we study which agents should become bankers, and when we highlight the role of their liabilities in facilitating payments.4

Relative to information-based theories, we focus on limited commitment (although imperfect monitoring is also part of the story). We are of course not the first to highlight commitment issues. Rajan (1998) has criticized standard banking theory on the grounds that it typically assumes agents have a perfect ability to contract, and argues instead for a model that rely on incomplete contracting, or incomplete markets, based on limited enforcement (see also Calomiris and Kahn 1991, Myers and Rajan 1998, and Diamond and Rajan 2001). We agree that limited enforcement or commitment should be central, but rather than taking the degree of market incompleteness as given, we want to delve into this a little further, using the tools of mechanism design.

While we think our approach to banking is novel, there is related work on money and credit, including Sanches and Williamson (2009), Nosal and Rocheteau (2009), Koepp, Monnet and Temzelides (2008), and Andolfatto (2008), and there is much work in general equilibrium with macro applications building on the models of limited commitment in Kehoe and Levine (1993, 2001). These papers all study environments that are similar to ours, although the applications are different.

4Work on the Diamond-Dybvig model is a large branch of the literature; see e.g. Jacklin (1987), Wallace (1988, 1990), Peck and Shell (2003), Green and Lin (2003), Andolfatto et al. (2007), and Ennis and Keister (2008). Usually these models do not interpret the bank as a self-interested agent, but as a contract or a mechanism, nor do they derive which agents should be bankers. In the papers that emphasize information sharing or delegated monitoring, banks are agents, but their role is restricted to solving information problems, and again they typically do not derive which agents will play this role. The fact that bank liabilities are useful in transactions is usually not discussed at all; for exceptions see Andolfatto and Nosal (2008), Huangfu and Sun (2008), Kiyotaki and Moore (2005), He et al. (2005, 2008), Cavalcanti and Wallace (1999a, 1999b), Wallace (2005), and Mills (2008), but arguably these are better characterized as papers in monetary theory trying to get something that looks like a bank into the model, rather than mainstream papers on banking that study the role of their obligations in the exchange process.
Commitment issues are central because banking concerns intertemporal reallocation, and we want to take seriously dynamic incentives to make good on one’s obligations. Agents in our model have investment opportunities, which they can in principle use as collateral to ameliorate commitment problems. But this does not work well if investments are easily liquidated – if e.g. a debtor can simply consume the proceeds, an investment cannot credibly be used as collateral.\(^5\) An implication is that delegated investment may be useful. If you deposit resources with a third party, who has less incentive or ability to liquidate for strategic reasons, others will be more willing to extend you credit. Thus, claims on deposits can facilitate other transactions, and this resembles banking. Other things being equal, it is better if a bank has good investment opportunities, but it may be efficient to sacrifice rate of return by depositing with one that is more trustworthy – i.e. less inclined to renege on obligations – since this helps facilitate other transactions. This puts in new perspective Hicks’ (1935) rate of return dominance puzzle: our agents hold assets with lower rates of return, because these aid in exchange, because they constitute the liabilities of more trustworthy parties that we interpret as banks.

The idea is obviously correct that sellers often accept the obligations of third parties, which throughout history took the form of notes, checks, credit/debit cards, or other instruments issued by commercial banks, when they would not accept one’s personal IOU. Of course this begs the question, why is a bank less inclined to renege on obligations? In the model, future rewards and punishments mitigate strategic behavior, so patience is relevant, but monitoring is imperfect (opportunistic behavior is detected only probabilistically). Agents with a higher likelihood of being monitored, or greater visibility, have more incentive to make good on obligations, and so they are better suited for the responsibility of accepting and investing deposits.\(^6\) However,

\(^5\)This is related to Kiyotaki and Moore (2008), Mills and Reed (2008), and references therein.

\(^6\)In terms of the literature, imperfect monitoring has been studied by many people, but in theories of money and banking it is worth mentioning Kocherlakota (1998), Kocherlakota and Wallace (1998), and Cavalcanti and Wallace (1999a, 1999b). Our version, where agents are monitored probabilistically, differs from theirs, and also from imperfect public monitoring in game theory where players cannot observe only signals about each other’s actions (see Mailath and Samuelson, 2006).
we go beyond simply assuming that some can be monitored while others cannot, by allowing agents to have different probabilities of gaining from economic activity, or different stakes in the system. Even with equal visibility, those with higher stakes are less inclined to deviate from proscribed behavior because they have more to lose. This allows us to endogenize monitoring when we analyze which agents, and how many, should be bankers.

Summarizing, we show that agents are better suited to perform the activities of banking (accepting and investing deposits) to the extent that they have a good combination of the following characteristics making them more trustworthy (less inclined to renege on obligations):

- they are relatively patient;
- they are more visible, or more easily monitored;
- they have a greater stake in, or connection to, the economic system;
- they have access to relatively good investment opportunities;
- they derive lower payoffs from liquidating investments for strategic reasons.

Some of these findings, like patience relaxing incentive constraints, may be obvious; we think that others are more subtle, like the idea that it can be better to delegate your investments to parties with a greater stake in the system, even if they have relatively poor investment opportunities, because their trustworthiness facilitates other transactions. And the results are consistent with at least our reading of economic history, as discussed below. Even when the conclusions are straightforward, we think the formal analysis is useful because it makes the effects and the nature of the trade-offs precise. This is the case when we study the trade-off between rate of return and facilitating transactions. And when we choose which agents to monitored and make bankers, we analyze how to select those with the right combination of the above-mentioned characteristics. Similarly, when we discuss the efficient number of
banks, we can lay out the trade-off between having fewer, which reduces monitoring costs, and having more deposits per bank, which increases the incentive to misbehave. All of this comes directly out of a mechanism design approach, without making assumptions about what is a bank, who is a bank, or what banks do.

The rest of the paper is organized as follows. Section 2 describes the basic environment, emphasizing the roles of temporal separation, limited commitment, collateral and monitoring. Section 3 characterizes incentive feasible and optimal allocations in a baseline version of the model. This version has a single group of agents that are heterogeneous with respect to type – so that at various points in time some want to borrow while others want to lend – but are homogenous within a given type. Section 4 considers multiple groups, in the sense that a given type can differ across groups with respect to visibility, connection to the system, etc. This section contains the main results on essentiality. Section 5 generalizes the analysis to discuss which individuals are best suited for banking, how to monitor when it is costly, and rate-of-return dominance. Section 6 reviews some banking history. Section 7 concludes.

2 The Environment

Time is discrete and continues forever. Agents belong to one of $N \geq 1$ groups, and in each group they can be one of 2 types. Within a group, agents of a given type are homogeneous, while across groups types can be heterogeneous. The role of heterogeneous groups will be clear later; for now we focus on a representative group with a set of agents $\mathcal{A}$. Each period, all agents of type $j$ in the group can be active or inactive, and we partition $\mathcal{A}$ into three subsets: inactive agents $\mathcal{A}_0$; active type 1 agents $\mathcal{A}_1$; and active type 2 agents $\mathcal{A}_2$. These sets have measure $\gamma_0, \gamma_1$, and $\gamma_2$, respectively, and type $j$ agents take as given that they belong each period to $\mathcal{A}_j$ or $\mathcal{A}_0$ with probabilities $\gamma_j$ and $1 - \gamma_j$. To ease the presentation, without affecting too many results, we set $\gamma_1 = \gamma_2 = \gamma$. Active agents can produce, consume, and

\footnote{No special restrictions on $\mathcal{A}$ are needed – it could be a continuum, countably infinite, or finite with as few as two agents.}
derive utility each period as described below. Inactive agents get utility normalized to 0, say, because they have no desire to consume or ability to produce, that period. Letting \( \gamma \) differ across groups captures the idea that they can have different degrees of connection to the economic system: a bigger \( \gamma \) means one has more frequent gains from trade, and hence more at stake.

In each period there are two goods, 1 and 2. Agents in \( A_1 \) consume good 1 and produce good 2, while agents in \( A_2 \) consume good 2 and produce good 1. Letting \( x_j \) and \( y_j \) denote consumption and production by type \( j \), we assume utility \( U^j (x_j, y_j) \) is increasing in \( x_j \), decreasing in \( y_j \), satisfies the usual differentiability and curvature conditions, and \( U^j (0, 0) = 0 \). When convenient, we also assume normal goods. A key friction is temporal separation: each period is divided in two, and good \( j \) must be consumed in subperiod \( j \). This generates a role for credit, since type 1 must consume before type 2. To have a notion of collateral, we assume good 2 is produced in the first subperiod and invested in some way that delivers goods for consumption in the second subperiod, with a fixed gross return \( \rho \geq 1 \). Investment here may be as simple as pure storage (perhaps for safe keeping). Or it could involve physical capital, or any other project; it is purely for simplicity that we assume a fixed return \( \rho \).

We do not allow type 2 agents to invest for themselves – or at least not as efficiently as type 1 – since if they could there would be no gain from intertemporal trade. Thus, only a producer of good 2, a type agent 1, can invest it. We sometimes (but only for the discussion of implementation at the end of Section 4) make the assumption that only type 1 can transport good 2 across groups, just like only type 1 can invest good 2 over time. Also, in the formal model agents all discount across periods at the same rate \( \beta \), but in the economic discussion we sometimes proceed as if patience differed across groups, since it is apparent what would happen if it did. This is mainly to reduce notation, but also to avoid some technical issues that can arise with heterogeneous discount rates. Our treatment of differences in patience is therefore

\[8\] There are no investment opportunities across periods, only across subperiods, again purely for simplicity.
relatively heuristic, but we still think it is useful. We are more rigorous in modeling
the difference in visibility, connection to the system, and the opportunity to liquidate
collateral.

Suppose we offer type 1 good 1, in exchange for good 2 that will be produced in
the first subperiod, invested, and delivered in the second subperiod. In a real sense,
they are getting a loan to consume good 1, with a promise to deliver good 2 later,
backed by their investment. Such a collateralized loan works very well if type 1 agents
get no payoff from consuming or otherwise liquidating the returns on the investment,
since when it comes time to deliver the goods, the production cost has been sunk.
To make it work less well, we let type 1 derive payoff $\lambda$ per unit liquidated out of
investments, over and above the payoff $U^1(x_1, y_1)$. If $\lambda = 0$, as we said, collateral
works well, but if $\lambda > 0$ there is an opportunity cost to delivering goods even if the
production cost is sunk. We assume $U^1(x_1, y_1) + \lambda y_1 \leq U^1(x_1, 0)$ for all $x_1$, so that
it is never efficient for type 1 to produce and invest for their own consumption. Also,
a type 1 agent derives the same liquidation payoff from any good 2, even if it was
produced by another type 1 agent, including one from a different group. But for type
$j = 1, 2$ agents in any group $i$, only goods produced within the same group $i$ enter
their utility functions (this is what defines a group).

We focus on symmetric and stationary allocations, given by vectors $(x_1^i, y_1^i, x_2^i, y_2^i)$
for each group $i$, and when there is more than one group, descriptions of cross-group
transfers, investment, and liquidation. We sometimes proceed with the discussion as
if the planner, or mechanism, collects all production and allocates it to consumers;
this is merely for convenience. The mechanism does not produce or invest goods –
the planner’s only job is to suggest ways to organize exchange. Assuming for the
moment that there are no transfers across groups or liquidation, since $\gamma_1 = \gamma_2 = \gamma$,
allocations are resource feasible if $x_1 = y_2$ and $x_2 = \rho y_1$, which means they can be
summarized by $(x_1, y_1)$. To reduce notation, we drop the subscript, and write $(x, y)$.
This completes the specification of the basic environment.
3 A Single Group

3.1 Baseline Results

For now, \( N = 1 \), so the only thing a planner or mechanism can do is recommend a resource-feasible allocation \((x, y)\) for the group. This recommendation is incentive feasible, or IF, as long as no one wants to deviate. Although we focus below on the case in which agents cannot commit to future actions, and hence may deviate whenever they like, we begin with benchmarks where they can commit to some degree. One notion is full commitment, by which we mean they can commit at the beginning of time before they even know their type. In this case, \((x, y)\) is IF as long as the total surplus is positive,

\[
S(x, y) \equiv U^1(x, y) + U^2(\rho y, x) \geq 0. 
\]  

Another notion is partial commitment, where agent can commit at the beginning but only after knowing their type. In this case, IF allocations are constrained by two participation constraints

\[
\begin{align*}
U^1(x, y) &\geq 0 \\
U^2(\rho y, x) &\geq 0.
\end{align*}
\]

With no commitment, at the start of each period, we face the participation conditions

\[
\begin{align*}
U^1(x, y) + \beta V^1(x, y) &\geq (1 - \pi) \beta V^1(x, y) \\
U^2(\rho y, x) + \beta V^2(x, y) &\geq (1 - \pi) \beta V^2(x, y),
\end{align*}
\]

where \( V^j(x, y) \) is the continuation value of type \( j \). In these conditions, the LHS is type \( j \)'s payoff from following the recommendation, while the RHS is the payoff from deviating, where as usual, without loss in generality we can restrict attention to one-shot deviations. A deviation is detected with probability \( \pi \), which results in a punishment to future autarky with payoff 0 (one could consider weaker punishments but this obviously is the most effective). But with probability \( 1 - \pi \), deviations go
undetected and hence unpunished. Since agents are active with probability $\gamma$ each period, $V^1(x, y) = \gamma U^1(x, y) / (1 - \beta)$ and $V^2(x, y) = \gamma U^2(\rho y, x) / (1 - \beta)$. From this it is immediate that the dynamic participation conditions hold iff (2)-(3) hold.

Moreover, type 1 consumes, produces and invests all in the first subperiod, in exchange for a promise to deliver good 2 in the second, but he can always renege and liquidate the investment for a short-term gain $\lambda \rho y$. If he is caught, he is punished with autarky, but again, he is only caught with probability $\pi$. This random monitoring technology, once we allow heterogeneity in $\pi$, captures the idea is that some agents are more visible than others, and hence less likely to get away with reneging on obligations. Thus, agent 1 delivers the goods in the second subperiod only if

$$\beta V^1(x, y) \geq \lambda \rho y + (1 - \pi) \beta V^1(x, y),$$

where the RHS involves a deviation by liquidating the investment, which is detected with probability $1 - \pi$. Inserting $V^1(x, y)$ and letting $\delta \equiv \lambda (1 - \beta) / \pi \gamma \beta$, this simplifies to what we call the repayment constraint

$$U^1(x, y) \geq \delta \rho y.$$  \hfill (4)

Notice that $\rho y$ is the obligation – promised payment – of type 1 when subperiod 2 rolls around, and $\delta$ is an effective discount rate he uses in contemplating whether to make good. Intuitively, a low monitoring probability $\pi$, a low rate of time preference $\beta$, a low stake in economic activity $\gamma$, or a high liquidation value $\lambda$ all make $\delta$ big, and hence increase the temptation to renege. We think it is fair to call an agent more trustworthy when he has smaller $\delta$, since this makes him less inclined to renege. More trustworthy agents can get bigger loans, precisely because they can credibly promise bigger repayments.

Let $\mathcal{F}_0$ denote the set of IF allocations with no commitment. Since (4) makes (2) redundant, $(x, y) \in \mathcal{F}_0$ satisfies the participation constraint (3) for type 2 and the repayment constraint (4) for type 1. For comparison, the IF set with partial commitment $\mathcal{F}_P$ satisfies (2)-(3), while the IF set with full commitment $\mathcal{F}_F$ only
requires $S(x, y) \geq 0$. Figure 1 shows $\mathcal{F}_0$ delimited by two curves defined by the relevant incentive conditions at equality,

\begin{align}
C_2 &\equiv \{(x, y) : U^2(\rho y, x) = 0\} \\
C_r &\equiv \{(x, y) : U^1(x, y) = \delta \rho y\}.
\end{align}

Clearly, $\mathcal{F}_0$ is convex and compact. It is nonempty, since $(0, 0) \in \mathcal{F}_0$, and it contains other points as long as there are gains from trade, which there are under the usual Inada conditions.

Let $\xi$ be the unique point other than $(0, 0)$ where $C_2$ and $C_r$ intersect, as shown in Figure 1. The following result will be useful:

**Lemma 1** If $\delta^b < \delta^a$, then $\xi^b$ lies northeast of $\xi^a$ in $(x, y)$ space.

**Proof:** An increase in $\delta$ rotates $C_r$ down, without affecting $C_2$. ■

We now define some notions of Pareto optimal, or PO, allocations. The ex ante PO allocation, which would seem most relevant under full commitment, is the $(x^o, y^o)$ that maximizes $S(x, y)$. With partial commitment, a welfare natural criterion is defined
by maximizing ex post welfare

\[ \max_{(x,y)} \mathcal{W}(x, y) = \omega_1 U^1(x, y) + \omega_2 U^2(\rho y, x) \]  

(7)

for some weights \( \omega_1 \) and \( \omega_2 \). As we vary these weights, we get

\[ \mathcal{P} = \left\{ (x, y) \mid \rho \frac{\partial U^1(x, y)}{\partial x} \frac{\partial U^2(\rho y, x)}{\partial y} = \frac{\partial U^2(\rho y, x)}{\partial x} \frac{\partial U^1(x, y)}{\partial y} \right\}, \]  

(8)

the contract curve. The core, which is a natural set to study under partial commitment, unconstrained by repayment, is \( \mathcal{K}_P = \mathcal{P} \cap \mathcal{F}_P \). One notion of the constrained core is \( \mathcal{K}_0 = \mathcal{P} \cap \mathcal{F}_0 \). While \( \mathcal{K}_P \) is nonempty as long as there are gains from trade, \( \mathcal{K}_0 \) might not be. Of course, we can define an alternative notion, say \( \mathcal{K} \), as the solution to (7) s.t. \( (x, y) \in \mathcal{F}_0 \) as we vary the weights. Since \( \mathcal{F}_0 \) is compact and \( \mathcal{W} \) is continuous, \( \mathcal{K} \neq \emptyset \).

The following rudimentary results are also useful:

**Lemma 2** \( \mathcal{P} \) defines a downward-sloping curve in \((x, y)\) space.

**Proof**: (8) defines \( y \) as a function of \( x \) with

\[ \frac{dy}{dx} = -\frac{\rho U^1_1 (U^2_{22} U^2_1 / U^2_2 - U^2_2) - U^2_2 (U^1_{11} U^1_1 / U^1_2 - U^1_2)}{\rho [U^2_1 (U^2_{22} U^2_1 / U^2_2 - U^2_2) - U^2_2 (U^1_{11} U^1_1 / U^1_2 - U^1_2)]}. \]

By the assumption that all goods are normal – i.e. in a standard utility maximization problem, for both types, consumption is increasing and production decreasing in wealth – all four terms in parentheses in \( dy/dx \) positive. \( \blacksquare \)

**Lemma 3** Let \((\hat{x}, \hat{y})\) maximize \( \mathcal{W}(x, y) \) s.t. \((x, y) \in \mathcal{F}_0 \). If the repayment constraint (4) is not binding then \((\hat{x}, \hat{y}) \in \mathcal{P} \).

**Proof**: Define the Lagrangian

\[ \mathcal{L} = \omega_1 U^1(x, y) + \omega_2 U^2(\rho y, x) + \eta U^2(\rho y, x) + \varphi [U^1(x, y) - \delta \rho y] \]  

(9)

where \( \eta \) and \( \varphi \) are multipliers. The FOCs are

\[ \omega_1 U^1_1 + \omega_2 U^2_1 + \eta U^2_1 + \varphi = 0 \]

\[ \omega_1 U^1_2 + \omega_2 \rho U^2_2 + \eta \rho U^2_2 + \varphi (U^1_2 - \delta \rho) = 0 \]
plus the constraints. Rearranging implies
\[
\frac{(\omega_1 + \varphi) U^1_1}{(\omega_1 + \varphi) U^1_2 - \varphi \delta \rho} = \frac{(\omega_2 + \eta) U^2_2}{\rho (\omega_2 + \eta) U^2_2}.
\]
If (4) is not binding then \( \varphi = 0 \), and \( \rho U^1_1/U^2_2 = U^2_1/U^2_2 \), which means \( (\hat{x}, \hat{y}) \in \mathcal{P} \). 

Figure 2 shows the IF set when we have no commitment \( \mathcal{F}_0 \), partial commitment \( \mathcal{F}_p \), and full commitment \( \mathcal{F}_F \), for an example with \( U^1(x, y) = \sqrt{x} - y \), \( U^2(\rho y, x) = \sqrt{\rho y} - x \), \( \beta = 3/4 \), \( \gamma = \pi = 1/2 \) and \( \rho = \lambda = 1 \). Clearly, \( \mathcal{F}_0 \subset \mathcal{F}_p \subset \mathcal{F}_F \), showing how commitment matters. In this example, \( \mathcal{K}_0 = \mathcal{P} \cap \mathcal{F}_0 \neq \emptyset \) (again, this is not always the case). Focusing on no commitment, since as we said an increase in \( \delta \) rotates \( C_r \) down but does not affect \( C_2 \), \( \mathcal{F}_0 \) and \( \mathcal{K} \) shrink when \( \delta \) increases. Also, \( \mathcal{F}_0 \) and \( \mathcal{K} \) shrink when \( \rho \) decreases.\(^9\) We think this is an interesting, albeit stylized, model of credit with imperfect commitment, monitoring and collateral. So far, however, it has nothing to say about banks; that comes in the next Section, along with heterogeneity across type 1 agents. Before proceeding, we mention some ways in which we can change the basic environment without affecting the main results.

\(^9\)This may be less obvious, since a change in \( \rho \) shifts both curves \( C_r \) and \( C_2 \) in \( (x, y) \) space; to easily verify the claim, redraw the picture in \( (x, \rho y) \) space.
3.2 Alternative Specifications

Rather than having permanently different types, suppose each agent is randomly selected to be type 1 or type 2 at every date. Then the continuation payoff is the same for all agents, \( V(x, y) = \gamma S(x, y)/(1 - \beta) \), where \( S \) is the surplus (1). Each period, after types are realized, the participation constraints are

\[
U^1(x, y) + \pi \frac{\gamma \beta}{1 - \beta} S(x, y) \geq 0
\]

\[
U^2(py, x) + \pi \frac{\gamma \beta}{1 - \beta} S(x, y) \geq 0
\]

while the repayment constraint is

\[
\lambda py \leq \frac{\pi \gamma \beta}{1 - \beta} S(x, y).
\]

Now we can have \( U^j < 0 \) for one type, and still satisfy these conditions, if \( S \) is big. The participation constraint for type 1 is no longer implied by the repayment constraint, so we must check all three conditions in defining \( F_0 \). Although the results go through, this complicates the analysis, and so we use permanent types in the base-line model.\(^{10}\)

Next, for those who do not like production, we can reinterpret the setup as a pure exchange economy. Again assume two permanent types, where now type \( j \) agents have preferences and endowments in the first and second subperiod \( u^j(x^j_1, x^j_2) \) and \((e^j_1, e^j_2)\). Without loss in generality, label types so that at their endowment points, type 1 has a greater MRS: \( u^1_1 / u^1_2 \geq u^2_1 / u^2_2 \). Now efficient allocations involve a loan \( L \geq 0 \) from type 2 to type 1 in the first subperiod, with repayment \( R \) in the second subperiod. Defining

\[
U^1(R, L) = u^1(e^1_1 + L, e^1_2 - R)
\]

\[
U^2(L, R) = u^2(e^2_1 - L, e^2_2 + R),
\]

this becomes a special case of our general model, with the opportunity cost of trading one’s endowment replacing the production cost. The participation condition for type

\(^{10}\)See the working paper Mattesini et. al. (2009) for all the details of the random-type model. In addition to being less tractable, an unnatural feature of that model is that, once we introduce banking, the bankers will be chosen randomly every period.
When $u_1^j = v(x_1^j) + \lambda x_2^j$ is quasi-linear, this reduces to $R \leq \delta U^1(L, R)$, with $\delta$ exactly as in the base-line model. This gives us a simple consumption-loan model with limited commitment, with endogenous credit limits determined by patience, monitoring, and connection to the market. However, it has no investment or collateral, which we want for our discussion of banking. Therefore, consider the following twist on the above specification. Suppose now that type 1 does not consume $e_1^1 + L$, but invests it in the first subperiod at return $\rho$. In the second period, he gives $R$ to type 2, who derives payoff $U^2(L, R)$, as above, while the investor consumes the residual for a payoff $U^1(L, R) = \lambda [\rho (e_1^1 + L) + e_2^1 - R]$. The repayment constraint is again $R \leq \delta U^1(L, R)$. Type 1 can be said to be borrowing for investment purposes, with the loan collateralized by the investment. Loan come out of endoments, and there is no production, per se.

We can also reinterpret the model as having neoclassical investment. Let type 1 be a firm with payoff $U^1(K, rK) = f(K) - rK$, where $f$ is a standard production function, and $r$ is the price of capital put in place in the first subperiod, paid in the second, after produciton is complete. Using the endowment version in the previous paragraph, we have $U^2(rK, K) = u^2(e_1^2 - K, e_2^2 + rK)$. Everything goes through as stated above, where now the participation constraint for type 1 can be interpetted as a non-negative profit condition, while his repayment constraint can be written

$$rK \leq \frac{\pi \beta \gamma f(K)}{1 - \beta (1 - \pi \gamma)}.$$

which says the repayment $rK$ cannot exceed an appropriately discounted measure of the future profit flow. Also, $\gamma$ can be interpreted as a productivity shock here. As this and other examples show, the framework is quite flexible.

Also, although we are generally interested in the entire IF set, one can impose various arbitrary mechanisms, and consider different notions of equilibrium. Gu and
Wright (2010) analyze equilibria with generalized Nash bargaining and Walrasian price taking. For the sake of illustration, suppose we partition active agents into pairs containing one agent of each type at the start of every period, and let type 2 make a take-it-or-leave-it offer. With partial commitment, equilibrium selects \((x, y) \in \mathcal{P}\) where the participation constraint for 1 holds at equality. With no commitment, this is not feasible: if \(U^1(x, y) = 0\) then 1 reneges for sure. Instead, equilibrium maximizes \(U^2(\rho y, x)\) s.t. \((x, y) \in \mathcal{F}_0\). This implies \((x, y) \in \mathcal{K}\) but \((x, y) \notin \mathcal{P}\). For the rest of the paper we study IF allocations, more generally, but since equilibrium for an arbitrary mechanism must be IF, our conclusions apply to equilibrium models as well.

4 Multiple Groups

For the points we want to make, consider \(N = 2\). Labeling the groups \(a\) and \(b\), for \(i = a, b\) we have: group \(i\) has two types \(1^i\) and \(2^i\), and two goods \(1^i\) and \(2^i\); specialized as above; both types are active each period with probability \(\gamma^i\); type \(1^i\) has liquidation value \(\lambda^i\); and we detect deviations with probability \(\pi^i\). For now \(\rho\), \(\beta\) and the cardinality of \(\mathcal{A}\) are the same in each group. Let \(\delta^i = \lambda^i (1 - \beta) / \pi^i \gamma^i \beta\) and consider the case \(\delta^a > \delta^b\). This means type \(1^a\) have more of a commitment problem than \(1^b\): if \(\mathcal{F}^i_0\) is the IF set for group \(i\), \(\mathcal{F}^a_0 \subset \mathcal{F}^b_0\). The IF set for the economy as a whole is given by allocations \((x^i, y^i)\) for each group, plus a description of liquidation, transfers and deposits, as discussed below, subject to the relevant incentive constraints. To be clear, recall type \(1^i\) can invest the output of group \(a\) or group \(b\), and the return and liquidation value are the same. Recall also that there are no gains from trade across groups for mercantile reasons, as goods \(1^a\) and \(2^a\) produced by group \(a\) do not enter the utility functions of agents in group \(b\), and vice versa. Hence, any interaction across groups will be solely due to incentive considerations.

11The relevant Lagrangian is given by (9) with \(\omega_2 = 1\) and \(\omega_1 = \eta = 0\). The first order conditions in this case rearrange to \(\rho(U^1_1 + \rho y)/U^2_1 = U^2_1/U^2_2\), which means \((x, y) \notin \mathcal{P}\) (the indifference curve for type 1 is steeper than for type 2). The inability to commit – or, perhaps rather, the ability to not commit – means type 1 does better at bargaining.

12We could allow \(\rho\) or \(\lambda\) to depend on which group produced the good, but it adds little other than notation. It is more interesting to let \(\rho\) and \(\lambda\) differ according to who invests the good.
4.1 Transfers

In addition to producing to invest their own output, suppose we have all type 1^b agents produce an extra $t > 0$ units of good 2^b and transfer it to type 1^a, who invest it, and liquidate the returns for their own benefit. Since there are $\gamma^b/\gamma^a$ active type 1^b agents for each active type 1^a agent, the payoffs are

$$
\hat{U}^1(x^a, y^a, t) \equiv U^1(x^a, y^a) + \lambda^a \rho t \gamma^b / \gamma^a 
$$

(10)

$$
\hat{U}^1(x^b, y^b, t) \equiv U^1(x^b, y^b + t).
$$

(11)

One can think of $t$ as a lump sum tax on type 1^b agents, the proceeds of which go to their counterparts in group a.\textsuperscript{13} Transfers in the other direction are given by $t < 0$, and it is never useful to have simultaneous transfers in both directions, given $U^1(x, y) + \lambda \rho y \leq U^1(x, 0)$. This scheme has incentive effects that we want to analyze for the following reason. We are ultimately interested in a different scheme, where output from one group is transferred to the other group to invest, but instead of liquidating it, they transfer the returns back to the first group for consumption. This delegated investment activity we claim is essential, in the sense that it can change the IF set. However, transfers also change the IF set. We claim that delegated investment can do more, and to make the case, we first analyze pure transfers.

With transfers, the participation conditions for type 2^i in each group i are as before,

$$
U^2(\rho y^i, x^i) \geq 0, \ i = a, b,
$$

(12)

but the repayment constraints for type 1^i change to

$$
\hat{U}^1(x^i, y^i, t) \geq \delta^i \rho y^i, \ i = a, b.
$$

(13)

The IF set with transfer $t$ satisfies (12) and (13).\textsuperscript{14} Notice $t$ only enters these conditions only through $\hat{U}^1(x^i, y^i, t)$. Thus, when it comes time to settle their obligations,

\textsuperscript{13} But note that the tax is not compulsory, in the sense that agents can always deviate to autarky.
\textsuperscript{14} To be clear, (13) is the incentive condition for type 1^i to make a payment to type 2^i – i.e. to agents in their own group. For a type 2^a agent, who is meant to liquidate the return from investing...
t affects the long-run (continuation) values for investors $1^a$ and $1^b$, but not the short-run costs or benefits to reneging. Since type $1^b$ are better off and type $1^b$ worse off in the long run the bigger is $t$, this scheme with $t > 0$ relaxes the repayment constraints in group $a$ and tightens them in group $b$. Whenever these constraints are binding in group $a$ but not $b$, this expands the IF set.

To see just how much we can accomplish with this scheme, consider the biggest transfer from group $b$ to $a$ subject to (12) and (13). This is a standard maximization problem, with a unique solution $\tilde{t}$ and an implied allocation $(\tilde{x}^i, \tilde{y}^i)$ for each group $i$. Since the RHS of constraint (13) is increasing in $\delta^b$, $\tilde{t}$ rises as $\delta^b$ falls (when agents are more patient, more visible, or more connected to the system, we can extract more from them). By way of example, let $U^1(x, y) = x - y$, $U^2(\rho y, x) = u(\rho y) - x$, and, to make the case stark, $\lambda^b = 0$. Then IF allocations in group $b$ solve

$$u(\rho y^b) - x^b \geq 0$$

$$x^b - y^b - t \geq 0.$$  

The maximum IF transfer and the implied allocation for group $b$ are given by: $\tilde{y}^b = y^*$, $\tilde{x}^b = u(\rho y^*)$, and $\tilde{t} = u(\rho y^*) - y^*$, where $y^*$ solves $\rho u'(\rho y) = 1$. Notice (14)-(15) hold with equality.

In this example, with transfer $\tilde{t}$, production by type $1^b$ agents $\tilde{y}^b$ is efficient, type $2^b$ agents give all of their surplus to $1^b$ by producing $\tilde{x}^b$, and we tax away the entire surplus of group $b$, because with $\lambda^b = 0$ we do not have to worry about repayment.\textsuperscript{15} Given the proceeds of this tax to type $1^a$ agents allows us to relax the incentive constraint in group $a$, since $1^a$ now have more to lose if they are caught cheating. Given them $\tilde{t}$ is the best we can do to relax their constraints, since if the tax were the transfer from group $b$, this can be written

$$\lambda^a \rho t_{1}^b / \gamma^a + \beta \tilde{U}^1(x^a, y^a, t)/(1 - \beta) \geq \lambda^a \rho (t_{1}^b / \gamma^a + y^a) + (1 - \pi)\beta \tilde{U}^1(x^a, y^a, t)/(1 - \beta).$$

This condition, which simplifies to (13), says type $1^a$ do not want to renege on their obligation by liquidating the return from investing their own output, after liquidating the return from investing the transfer.\textsuperscript{15} We can easily relax $\lambda^b = 0$. In general, in this example, the maximum transfer is $\tilde{t} = u(\rho y) - \left(1 + \delta^b \rho\right) \tilde{y}$, where $\rho u'(\rho y) = 1 + \delta^b \rho$. Notice $\partial \tilde{y} / \partial \delta^b < 0$ and $\partial \tilde{t} / \partial \delta^b < 0$. 

\textsuperscript{15}
bigger there would be defection by group $b$. The main point is that transfers can change the IF set. This is no surprise; we present the results so we can conclude below that deposits can do even more.

4.2 Deposits

Let $d \geq 0$ denote deposits, defined as follows. Deposits are units of good $2^a$ produced by type $1^a$ and transferred to type $1^b$, who invest it, but rather than liquidating the return as they did with pure transfers, now type $1^b$ agents pay it back to group $a$ for consumption by type $2^a$. As with pure transfers, we can consider deposits going the other way by setting $d < 0$. We call this delegated investment, since $d > 0$ entails $1^b$ investing the output of $1^a$, Clearly, this has nothing to do with $1^b$ having better investment opportunities than $1^a$, since for now $\rho$ is the same for both groups (later we show this scheme can be useful even when $\rho^b < \rho^a$). Instead, it is all about incentives.

We still face the participation conditions (12) for type $2^i$ in each group, but the repayment conditions change as follows. Since type $1^a$ is now only obliged in the second subperiod to pay $\rho (y^a - d)$, their constraint is

$$\hat{U}^1(x^a, y^a, t) \geq \delta^a \rho (y^a - d),$$

and since type $1^b$ is obliged to pay $\rho (y^b + d\gamma^a/\gamma^b)$, theirs is

$$\hat{U}^1(x^b, y^b, t) \geq \delta^b \rho (y^b + \gamma^a d/\gamma^b),$$

where these conditions allow transfers, in addition to deposits, since they use the payoffs defined in (10) and (11). We also face a resource constraint

$$0 \leq d \leq y^a.$$  

Putting these together, the IF set with deposits $F_d$ is given by an allocation $(x^i, y^i)$ for each group $i$, together with $t$ and $d$, satisfying (12) and (16)-(18). Notice that

---

16We take as the base case deposits going from group $a$ to group $b$, while transfers went the other way, because both achieve the effect of relaxing the repayment constraints in the group with the bigger incentive problem.
we relax the repayment constraint in group \(a\) while tightening it in group \(b\) with \(d > 0\), as we did before with \(t > 0\). But it is critical to understand that deposits are different than transfers in how they impact incentives: \(t\) only affects continuation payoffs, while \(d\) affects directly the within-period benefits to reneging by changing the obligations of types \(1^a\) and \(1^b\). With this in hand, we can present the result that delegated investment is essential, in the sense that if we start with \(d = 0\), and then introduce deposits, the IF set expands.\(^{17}\)

**Proposition 1** \(\mathcal{F}_0 \subset \mathcal{F}_d\) and for some parameters \(\mathcal{F}_d \setminus \mathcal{F}_0 \neq \emptyset\).

**Proof:** Since any allocation in \(\mathcal{F}_0\) can be supported once deposits are allowed by setting with \(d = 0\), it is trivial that \(\mathcal{F}_0 \subset \mathcal{F}_d\). To show that more allocations may be feasible with deposits, it suffices to give an example. To make the example easy, set \(\lambda^b = 0\), so that holding deposits does not affect the incentive constraints for group \(b\). We claim that there are some allocations for group \(a\) that are only feasible with \(d > 0\). To see this, set \(t = \tilde{t}\) to maximize the transfer from group \(b\) to \(a\), as discussed in the previous section. Given \((x^b, y^b, t) = (\tilde{x}^b, \tilde{y}^b, \tilde{t})\), all incentive constraints are satisfied in group \(b\). In group \(a\), the relevant conditions (12) and (16) are

\[
U^2(\rho y^a, x^a) \geq 0
\]

\[
\hat{U}^1(x^a, y^a, \tilde{t}) \geq \delta^a \rho (y^a - d)
\]

For any allocation such that \(\delta^a \rho y^a \geq \hat{U}^1(x^a, y^a, \tilde{t})\), \(d > 0\) relaxes the repayment constraint and hence expands the IF set. For an explicit parametric example, see the end of this Section. ■

Note that while the example in the proof has \(\lambda^b = 0\), which means \(1^b\) agents have no incentive to renege and their investments are perfect collateral, it is easy to construct examples with \(\lambda^b > 0\) (see Mattesini et al. 2009). Also, notice that as long as it does not violate the repayment constraint for \(1^b\), which is certainly the case

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\(^{17}\)Notice that we are not claiming \(\mathcal{F}_0 \subset \mathcal{F}_d\) for any fixed \(d = \tilde{d} > 0\), since then the repayment constraint in group \(b\) may be violated for some allocation in \(\mathcal{F}_0\). The claim is rather that deposits are essential when we get to choose \(d\).
when \( \lambda^b \approx 0 \), we could always set \( d = y^a \) and let \( 1^b \) invest all of the output of \( 1^a \). In this case the repayment constraint for \( 1^a \) reduces to \( \tilde{U}^1(x^a, y^a, \tilde{t}) \geq 0 \), which is their participation condition. Thus, when \( \lambda^b \) is small, having agents in group \( a \) delegate all of their investment eliminates entirely their commitment problem. A similarly extreme but interesting case is \( \pi^a \approx 0 \), which means \( 1^a \) never repays a loan. In this case, which is like lending to a complete stranger, credit, investment and exchange cannot get off the ground started unless \( 1^a \) deposits with \( 1^b \).

As an example, consider \( U^1(x, y) = u(x) - y, U^2(y, x) = y - x \), where the two groups share the same parameters, \( \rho = 1, \delta^i = \delta, \lambda^i = \lambda < 1 \) and \( \omega^i_1 = 1 \). The latter implies that agents of type 2 will have no surplus, so that \( x^i = y^i \) in both groups. Using this fact, the IF sets in group \( a \) and \( b \), when group \( b \) makes a transfer \( t \) and accepts deposits \( d \), are defined by the set of \( x_a \) and \( x_b \), respectively, satisfying

\[
\begin{align*}
\quad u(x^a) - x^a + \lambda t & \geq \delta (x^a - d) \\
\quad u(x^b) - x^b - t & \geq \delta (x^b + d)
\end{align*}
\]

We obtain the IF sets when group \( a \) makes a transfer and accepts deposits in a similar way. We want to illustrate that deposits expand the IF sets beyond what is achieved with transfers. To see this, notice that increasing transfers relaxes the repayment constraint for group \( a \) (19) by \( \lambda t \) while tightening (20) by \( t \). Now, consider deposits \( d = \lambda t / \delta \). This relaxes (19) for group \( a \) by the same amount, \( \lambda t \). But it only tightens (20) for group \( b \) by \( \lambda t < t \). Therefore to obtain the same level of slack for groups \( a \)'s repayment constraint requires less tightening for group \( b \) when deposits are used. Figure 3 shows the IF sets for group \( a \) (x-axis) and \( b \) (y-axis) in three cases: \( t = d = 0 \) is shown by the red square; using transfers from group \( b \) to group \( a \), but no deposit, the IF set in group \( a \) expands by the dark blue area. Symmetrically, using transfers from group \( a \) to group \( b \), the IF set of group \( b \) expands by the dark red area. Using deposits in group \( b \), the IF set in group \( a \) expands some more, now also including the light blue area (and symmetrically, group \( b \)'s IF set expands by the light red area, when group \( a \) takes deposits from group \( b \)).
To review the key ideas, suppose you want consumption now, and pledge to deliver something in return out of your investments. When the time comes to make good, you are faced with a temptation to renege and liquidate the investments for your own benefit. This limits your credit. By depositing resources with a third party, who invests it for you, the temptation is relaxed. Of course, we must consider the temptation of the third party, in general, although this is a non-issue if $\lambda^b \approx 0$. But as we said, even if $\lambda^b > 0$, as long as the third party is more trustworthy, $d > 0$ can be beneficial, as it allows you to get more on credit than a personal IOU. We interpret the third party as a bank, since it accepts deposits and makes investments, and moreover its liabilities (claims on deposits) help to facilitate transactions. They facilitate transactions in the sense that you get more credit if your promise of repayment is backed by deposits – by the banker’s good name, so to speak.

Although we are less concerned with details of implementation than with describing feasible allocations, the following discussion should make it even clearer that type $1^b$ agents resemble bankers. A question one might ask is, how should we keep track of all the transfers between agents? One way, which is especially nice when record keeping is costly, is this: When type $1^a$ wants to consume, in the first subperiod, he
produces and deposits the output with type $1^b$ in exchange for a receipt. He gives type $2^a$ the receipt in exchange for good $1^a$. Type $2^a$ takes this receipt, which is backed by a promise of $1^b$, while he would less readily accept the personal promise of $1^a$. Type $2^a$ carry the receipt until they want to consume, when they redeem it for good $2^a$. Banker $1^b$ pays $2^a$ out of deposits – principle plus returns on investment – which “clears” the receipt. The same banker $1^b$ generally makes also payments to group $b$ depositors from the returns on investing his own output. This works because the bank is trustworthy.

To us, this clearly resembles banking, with receipts acting as inside money, as have various bank-issued instruments over time, from notes to checks to debit cards. When we say it resembles banking, we mean that this activity is consistent with what the general public and standard references regard as banking. As Selgin (2006) puts it, “Genuine banks are distinguished from other kinds of financial intermediaries by the readily transferable or ‘spendable’ nature of their IOUs, which allows those IOUs to serve as a means of exchange, that is, money. Commercial bank money today consists mainly of deposit balances that can be transferred either by means of paper orders known as checks or electronically using plastic ‘debit’ cards.” And we repeat that it is desirable for $1^a$ to deposit and delegate investments to $1^b$ even though the latter, like most actual banks, does not offer a particularly good return. What the bank does offer is something one could call liquidity – holding claims against their investments allows one to turn wealth more easily into consumption.

We like the story about circulating receipts for several reasons, including their advantage in terms of record keeping, but there could in principle be other ways to proceed. Commenting on an earlier version of the model, Chris Phelan suggested that $1^a$ could give output to $2^a$, instead of a receipt, then $2^a$ could give it to $1^b$ to invest. This also looks something like banking, or delegated investment, although it does not have the receipts circulating as inside money, and it is only beneficial because $1^b$ has better investment opportunities (remember that $2^a$ cannot invest at all). In any case, we can rule out this arrangement with the assumption that $2^a$ agents cannot transport first-subperiod goods (just like they cannot invest them). This means the receipts, which anyone can transport, end up circulating. This story follows a long tradition of determining which objects are used as means of exchange based on intrinsic properties, like storability and portability, going back at least to Menger (1892).

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5 Extensions and Applications

Having shown that deposit banking is essential, we now explore several related issues. We first study who should hold deposits – while in the previous section we took for granted that it should be $b$. We then study how to monitor when it is costly. Finally, we expand on the rate-of-return dominance issue.

5.1 Who Should Hold Deposits?

Suppose again that we have two groups with $a > b$. We now show that it may be desirable, in a Pareto sense, to have group $a$ deposit resources with group $b$ agents, but it is never desirable in this sense to have group $b$ deposit with group $a$. Let $(\hat{x}^i, \hat{y}^i)$ be the best IF allocation for group $i$ with no transfers or deposits, solving

$$\max_{x^i, y^i} W^i(x^i, y^i) \text{ s.t. } (x^i, y^i) \in F^i_0,$$  \hspace{1cm} (21)

where welfare $W$ was defined in (7), given some weights. At $(\hat{x}^i, \hat{y}^i)$, obviously, no IF allocation for group $i$ makes $i$ better off without making $2^i$ worse off, and vice-versa.

Then we ask, given $(\hat{x}^a, \hat{y}^a)$ and $(\hat{x}^b, \hat{y}^b)$, can we make agents in one group better off without hurting those in the other? Clearly transfers cannot help, in this regard, since the group making the transfer is always worse off.

Given this, here we ignore transfers, and only study deposits. If deposits can help, we say they are Pareto essential, or PE.\footnote{To explain this usage, recall that essential means the IF set becomes bigger or better. Here we mean better, according to the Pareto criterion, and so we use PE.} That is, consider the allocation $(\tilde{x}^i, \tilde{y}^i)$ that, for some $d$, solves

$$\max_{\tilde{x}^i, \tilde{y}^i} W^i(\tilde{x}^i, \tilde{y}^i) \text{ s.t. } (\tilde{x}^i, \tilde{y}^i) \in F^i_d.$$

Deposits are PE if there is $d$ such that $W^i(\tilde{x}^i, \tilde{y}^i) \geq W^i(\hat{x}^i, \hat{y}^i)$ for both $i$ with one strict inequality. A necessary condition for PE in group $i$ is that the repayment constraint does not bind at $(\hat{x}^i, \hat{y}^i)$, since otherwise, deposits will make the repayment constraints tighter, shrink the IF set, and lower $W^i$. We can now give the following result.
**Proposition 2** Deposits are PE if and only if the repayment constraint binds for only one group.

**Proof:** Consider \((\hat{x}^i, \hat{y}^i)\) be the best IF allocation for group \(i\) with no transfers or deposits. Notice that deposits only affects the repayment constraint. There are two possible cases possible for each group \(i\): By Lemma 3, either the repayment constraint is binding or it is not binding at \((\hat{x}^i, \hat{y}^i)\). If the repayment constraint binds for both groups, then \(d \neq 0\) will tighten the RC in one group, thus making it worse off. Hence in this case, deposits cannot be PE. If the repayment constraint does not bind in any group, then deposits may make one group worse off (as its feasible set shrinks) and none better off. So in this case as well, deposits cannot be PE. Finally, consider the case where the repayment constraint binds for one group but not for the other. Introducing deposits relaxes the repayment constraint in the group where it binds, so that a better allocation becomes feasible there. For sufficiently small deposits, the repayment constraint in the other group, while tighter, will still be slack. Therefore, in this case, deposits are PE. ■

For some economies, it is not possible that the repayment constraint binds in group \(b\) while it does not bind in group \(a\). Therefore, in these economies, bankers will be selected from group \(b\). For example, this is the case if \(\rho^a = \rho^b, \omega_1^a = \omega_1^b\) and \(\delta^a > \delta^b\). In this economy, \(\mathcal{F}_0^a \subset \mathcal{F}_0^b\) and since the welfare weights are the same across groups, if the repayment constraint does not bind in group \(a\) at \((\hat{x}^a, \hat{y}^a)\) then it cannot bind in group \(b\) either. Therefore, everything else constant, bankers should originate from the group with the lower commitment problem, i.e. the lower \(\delta\). This is illustrated in Figure 4, for the case in which \((x^*, y^*)\) is not feasible in either group. When \(d = 0\), \((\hat{x}^b, \hat{y}^b) \in \mathcal{P}\) solves (21) for group \(b\), but the commitment problem is so severe in group \(a\) that \((\hat{x}^a, \hat{y}^a) \notin \mathcal{K}_p^a\). Introducing \(d > 0\) shifts the repayment constraint for group \(b\) in and the one for group \(a\) out. This has no effect on group \(b\) since \((\hat{x}^b, \hat{y}^b)\) is still feasible, but makes group \(a\) better off since a superior allocation \((\tilde{x}^a, \tilde{y}^a)\) is now feasible. Hence we can make group \(a\) better off without hurting group
b with $d > 0$, but we cannot make group $b$ better off without hurting group $a$.

As another example, consider the economy where $\rho^a = \rho^b$, $\omega_1^a < \omega_1^b$ and $\delta^a = \delta^b$, then again, the repayment constraint in group $b$ will not be binding if it does not bind in group $a$. In this example, the feasible sets are the same across groups. But the planner treats agents 1 in group $a$ worse than agents 1 in group $b$. Therefore if the repayment constraint does not bind in group $a$ at $(\hat{x}^a, \hat{y}^a)$ it will not bind in group $b$ at $(\hat{x}^b, \hat{y}^b)$ either. Finally, consider the example where $\rho^a < \rho^b$, while $\omega_1^a = \omega_1^b$ and $\delta^a = \delta^b$. In this case, $\mathcal{F}_0^a \subset \mathcal{F}_0^b$ and the same argument as above applies.

To conclude, keeping everything else constant, bankers should be selected from the group with the higher weight on type 1 agents, the lesser commitment problem, or the better investment opportunities.

5.2 How Should We Monitor?

We now consider efficiency when monitoring is costly. By choosing monitoring intensity we endogenize $\delta^a$ and $\delta^b$. Assume monitoring group $i$ with probability $\pi^i$ implies
a utility cost $\pi^i k^i$ on agents of group $i$. Define a new benchmark with $d = 0$ in group $i$ as the solution $(x^i, y^i, \pi^i)$ to

$$\max_{(x,y,\pi)} \mathcal{W}^i(x,y) - \pi k^i \quad \text{s.t.} \quad x \in \mathcal{F}^i_0 \quad \text{and} \quad 0 \leq \pi \leq 1.$$  

(23)

Clearly, the repayment constraint must be binding, $U^1(x^i, y^i) = \delta^i py^i$, since otherwise we could reduce monitoring costs. Also, notice that $(x^*, y^*)$ is typically not efficient when monitoring is endogenous, since reducing $\pi$ implies a first order gain while moving away from $(x^*, y^*)$ entails only a second order loss.

In this application we are interested in minimizing total monitoring costs, rather than asking if deposits are PE.\(^{20}\) Also, for now we assume there is exactly one active agent in each group at each date, which means there is a single candidate banker in each group (below we also discuss what happens more generally). Note that we can still have different $\gamma^a$ and $\gamma^b$, if we relax the assumption that $\mathcal{A}^a$ and $\mathcal{A}^b$ have the same cardinality. Obviously, if agents in one group deposit their production with the other group, we can reduce the cost of monitoring the former, but at the expense of increasing monitoring in the latter. Still, this may be desirable, if there are differences across groups in the costs of monitoring $k^i$ or the incentives to deviate, as captured by $\gamma^i$ and $\lambda^i$. In the Appendix, we prove that if $\gamma^b \geq \gamma^a$, $\lambda^b \geq \lambda^a$, and $k^b \leq k^a$ then $d > 0$ may be desirable, while $d < 0$ cannot be. Also, we show that when $\gamma^b$ is large enough, so type $1^b$ has a big enough stake in the economy, he should hold all of the deposits, so that we can give up monitoring type $1^a$ entirely.

**Proposition 3** Fix $(x^a, y^a)$ and $(x^b, y^b)$. If $\gamma^b \geq \gamma^a$, $\lambda^b \geq \lambda^a$, and $k^b \leq k^a$, then efficient monitoring implies $\delta^b < \delta^a$. Also, if $\gamma^b$ is above a threshold $\bar{\gamma}$ (defined in the proof) then $\pi^a = 0$.

Next, consider an application where monitoring costs are borne by the type $1^i$ in each group. We show deposits in group $b$ can be desirable when $1^a$ must compensate

\(^{20}\)With transferable utility and $\omega_1 = \omega_2 = \omega$, we can use transfer $t$ to compensate type $1^b$ for the increase in monitoring cost and tax type $1^a$ for decrease in monitoring cost, and any decrease in total monitoring cost with transfer is Pareto improving.
For increasing monitoring in group $b$. For the sake of this example, we set $\rho = 1$, $U^1(x, y) = x - y$, $U^2(y, x) = u(y) - x$, and, to ease the presentation, distinguish between the probability of monitoring participation, which we fix at $\pi = \pi^i$ in both groups, and monitoring repayment, which we denote by $p^i_d$ in group $i$ when deposits are $d$. The monitoring cost is paid up front (and only once) by $1^a$ and $1^b$. The participation and repayment constraints with deposits $d$ and transfers $t$ are

\[
\begin{align*}
\forall i, & \quad u(y^a) - x^a \geq 0 \quad x^a - y^a - t - p^a_d k^a + \theta^a (x^a - y^a) \geq 0 \\
& \quad x^a - y^a \geq \delta^a (y^a - d) \\
& \quad u(y^b) - x^b \geq 0 \quad x^b - y^b + \lambda^b t - p^b_d k^b + \theta^b (x^b - y^b) \geq 0 \\
& \quad x^b - y^b \geq \delta^b (y^b + d)
\end{align*}
\]

where $\delta^i = \lambda^i (1 - \beta) / (p^i_d \gamma^i \beta)$ and $\theta^i = \pi^i \gamma^i \beta / (1 - \beta)$. Notice that the participation constraints for agents $1^i$ are no longer redundant. An allocation is feasible if there is a $p^i_d \leq 1$ such that the above constraints hold.

In the Appendix, we show high $x^2_2$ is feasible if $\beta$ is high, $\lambda^i$ is low, or $k^i$ is low, verify that the repayment constraints always bind, when $d = t = 0$, and characterize the monitoring probability $p^i_0$ and total monitoring cost $c = p^a_0 k^a + p^b_0 k^b$. Now consider $d > 0$ and $t > 0$. If $d$ and $t$ are small enough, the monitoring probabilities are given by the repayment constraints at equality, and

\[
\begin{align*}
\forall i, \quad c &= \frac{y^a - d}{x^a - y^a} \delta^a p^a_d k^a + \frac{y^b + d}{x^b - y^b} \delta^b p^b_d k^b.
\end{align*}
\]

With deposits, the change in the monitoring cost is

\[
\Delta c = \frac{\delta^b p^b_d k^b}{x^b - y^b} - \frac{\delta^a p^a_d k^a}{x^a - y^a}
\]

For $d > 0$ to reduce $c$, we therefore need

\[
\frac{\lambda^b k^b}{\gamma^b (x^b - y^b)} \leq \frac{\lambda^a k^a}{\gamma^a (x^a - y^a)}.
\]
To make sure $1^b$ is willing to incur the additional monitoring cost, $1^a$ should free up enough resources to compensate by reducing his own monitoring cost, or

$$\bar{t} = \frac{\delta^a p^a k^a d}{x^a - y^a},$$

(24)

and the liquidation value of $\bar{t}$ must cover the extra monitoring cost of $1^b$, which means

$$\lambda^b \bar{t} \geq \frac{\delta^b p^b k^b d}{x^b - y^b}.$$  

(25)

Summarizing, agent $1^b$ is better off with $d > 0$ when

$$\frac{k^b}{\gamma^b (x^b - y^b)} \leq \frac{\lambda^a k^a}{\gamma^a (x^a - y^a)}.$$

**Proposition 4** Let $U^1(x, y) = x - y$ and $U^2(y, x) = u(y) - x$. Given we have to compensate agents with transfers for any increase in monitoring costs, $d > 0$ is desirable iff

$$\max\{1, \lambda^b\} \frac{k^b}{\gamma^b (x^b - y^b)} \leq \frac{\lambda^a k^a}{\gamma^a (x^a - y^a)}.$$

Finally, we briefly mention that there is an interesting trade off when one considers the efficient number of bankers generally. Fewer bankers reduce total monitoring cost, but imply more deposits per banker, as a consequence we must monitor them more vigorously. In fact, even if there is only one group, if one is willing to consider asymmetric allocations, it can be desirable to designate some subset as bankers, and concentrate all monitoring efforts on them. For illustration, we consider the last example, but now assume a monitoring cost function $k_0 + pk$ with increasing returns. Suppose there are $n$ active type $1^b$ agents, and therefore $n$ potential bankers. Given an allocation and deposits $d$, the monitoring probability if there is a single banker is given by the binding repayment constraint,

$$p_1 = \frac{\lambda^b k^b (ny^b + d)}{\gamma^b (x^b - y^b)}.$$

Notice the banker now has to invest his own production $y^b$, deposits from type $1^a$, and deposits from other type $1^b$ agents, $(n - 1) y^b$. Total monitoring costs are $k_0 + p_1 k$.  

30
Now suppose we increase the number of bankers from one to \( m \leq n \). The monitoring probability is

\[
p_m = \frac{\lambda^b k^b (ny^b + d)}{m \gamma^b (x^b - y^b)} = \frac{p_1}{m},
\]
as total investment can be split across \( m \) separate bankers. Total monitoring cost becomes \( m (k_0 + p_1 k/m) = mk_0 + p_1 k \), higher than with a single banker. Also, we have assumed that \( y^b \) is feasible with a single banker in group \( b \). If this is not true, there is a minimum number of bankers necessary to sustain \( y^b \), say \( m^* \). Guaranteeing \( y^b \) is feasible given \( d \), we must satisfy \( p_{m^*} = 1 \). This is also the optimal number of bankers in this application, and is given by

\[
m^* = \frac{\lambda^b k^b (ny^b + d)}{\gamma^b (x^b - y^b)}.
\]

Thus, we can say e.g. that there should be fewer bankers when there are fewer resources to invest, where the bankers have more at stake, or when they have lower liquidation values.

### 5.3 Rate Of Return Dominance

In this section, we show that efficient bankers need not have the best investment opportunities, if they are relatively better at commitment. This implies a simple rate of return dominance result. Consider the case where each unit invested in group \( i \) returns \( \rho^i \), different across groups. We show that, for some parameters, deposits in group \( b \) are PE, despite a better investment technology in group \( a \). Intuitively, this explains why individuals keep wealth in demand deposits, despite the existence of alternative investments with higher returns: The agents holding these deposits can be counted on to make good on their obligations, making their liabilities good payment instruments.

**Proposition 5** For all \( \delta^b < \delta^a \) there exists \( \rho^b < \rho^a \) such that \( d > 0 \) is PE.

**Proof:** The proof is by continuity: First consider the case where \( \rho^i = \rho \) for all \( i \). By Theorem 2 and the following discussion, we know that \( d > 0 \) is PE when
But for sufficiently small \( \varepsilon \), this is also the case when \( \rho^b = \rho - \varepsilon \): introducing deposits will relax the repayment constraint in group \( a \) (although less than before), thus making them better off. It will tighten it in group \( b \), but since it was not binding in group \( b \) in the first place, they will be as well off as before.

Notice that there is a trade-off between commitment and return: When group \( a \) deposits resources with group \( b \), they have to give up the return \( \rho^a \). When the difference between investment returns across groups is large it is well possible that deposits in sector \( b \) are no longer PE: Giving up \( \rho^a \) may actually tighten the repayment constraint, as agents 1 now have to produce more to sustain the same level of consumption. In the Appendix, we analyze this trade-off for an example.

To summarize, the key message here is that bankers are not necessarily agents with the best investment opportunities, and for deposits to be used efficiently in payments they do not necessarily have to have the greatest return. This is important when we consider the circulation of bank liabilities: It is not because some investment have a greater return that agents will trade claims on these investments. Rather, because of the commitment issue that can plague the owner of the best project, agents may prefer to trade using lower-interest-bearing assets. So our theory provides a novel explanation for the long-standing rate of return dominance puzzle.

6 A Brief Digression on History

We have established that, because of incentive issues, it can be beneficial for an agent who wants credit from a second agent to deposit resource with a third party – an intermediary – who invests on his behalf until they are withdrawn by the second party. The reason is that the third party may be more credible, or more trustworthy, in terms of honoring his obligations. He can be more trustworthy because he is more patient, because he is more visible, because has more at stake in the economic system, or because his gains from liquidating the investment and absconding with the returns are lower. This arrangement can be efficient, even if the third party does not have
access to the highest-return investment opportunities. As we said, we think this resembles banking. In this section we go into a little more detail on the history of banking.

We begin by mentioning that, although the deposit receipts discussed above constitute inside money, our theory of banking involves no outside money, since our deposits are real commodities. Although it may be interesting to also include outside money in future work, we point out that, from the historical perspective, institutions that accepted deposits in goods came long before the invention of coinage in the 7th century. In ancient Mesopotamia and Egypt, e.g., mainly for security, and to economize on transportation costs, goods were often deposited in palaces and temples and, in later periods, also private houses. As Davies (2002) describes the situation:

Grain was the main form of deposits at first, but in the process of time other deposits were commonly taken: other crops, fruit, cattle and agricultural implements, leading eventually and more importantly to deposits of the precious metals. Receipts testifying to these deposits gradually led to transfers to the order not only of depositors but also to a third party. In the course of time private houses also began to carry on such deposit business ... The banking operations of the temple and palace based banks preceded coinage by well over a thousand years and so did private banking houses by some hundreds of years.

We think that it is especially interesting that deposit receipts so long ago led to transfers to the order of third parties, so they could facilitate transactions and payments, like the receipts discussed in the context of the model. Relatedly, in his detailed description of the medieval Venetian bankers, Mueller (1997) describes the practice of accepting two types of deposits: regular deposits, which were specific goods that bankers had to deliver on demand; and irregular deposits, involving specie or coins that only had to be repaid with the same value, not the same specie or coins. The depositor making an irregular deposit tacitly agreed to the investment by the
banker of the deposits. Like in modern times, when you put currency in the bank, you do not expect to withdraw the same currency later, only something of some specific value. This is true in the model too: the liability of the bank is not the deposit of goods, per se, but claims on the returns to its investments.\(^{21}\)

Many regard the English goldsmiths as the first modern bankers. Originally, their depositors were again mainly interested in safe keeping, which is a simple type of investment. But early in the 17th century their deposit receipts began circulating in place of money for payment purposes – the first incarnation of British banknotes – and shortly thereafter they allowed deposits to be transferred by “drawn note” or cheque. Nice discussions of the English goldsmith bankers can be found in Encyclopedia Britannica (we looked at the 1941 and 1954 editions). For more specialized treatments, see Joslin (1954) and Quinn (1997). Although many call the goldsmiths the first modern bankers, others give this credit to the Templars (see Weatherford 1997 or Sanello 2003). During the crusades, because of their skill as warriors, these knights became specialists in protecting and moving money and other valuables. At some point, rather than e.g. shipping gold from point A to point B for one party and shipping different gold from point B to point A for another, they saved on security and transportation costs simply by reassigning the parties’ claims to gold in different locations; we are aware, however, of no evidence that their liabilities were used as a medium of exchange, as were goldsmiths’ receipts.

It is also interesting to note that other institutions that engaged in the type of banking we have in this paper – accepting deposits of goods that facilitate other transactions and credit arrangements – were still common after the emergence of modern banking. Because they are making investments, our bankers are more than pure storage facilities. We emphasize this because Chris Phelan in another comment on an earlier version of the paper said that, according to our theory, coat-check girls at restaurants are bankers. Not quite. When you give your hat to a coat-check girl you expect the same hat back after dinner; when you give your income to a banker you expect something different. Still, there is something to his comment, since most people agree that the origin of deposit banking did revolve around safe keeping and convenience. It would be easy to introduce sake-keeping considerations formally into the model if we added theft as in He et al (2005, 2008) or Sanches and Williamson (2008). Similarly, one could also introduce counterfeiting considerations; see e.g. Nosal and Wallace (2007) and the references therein.

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banks. In colonial Virginia, e.g., tobacco was commonly used in transactions because of the scarcity of precious metals (Galbraith 1975). The practice of depositing tobacco in public warehouses and then exchanging authorized certificates, attesting to its quality and quantity, was extremely common and survived for over 200 years. Similarly, in the 19th century, to facilitate transactions and credit arrangements between cocoon producers and silk weavers, banks established warehouses that stored dried cocoons or silk and issued warrants that could be used to pledge for credit. So while it may be interesting to discuss banking in modern monetary economies, we think it is also interesting and historically relevant to discuss banking without outside money.

The main thing to take away from the above examples is that an early development in the evolution of banking was for deposits to be used to facilitate exchange. As in the model, throughout history, a second party is more likely to give you something if you can use in payment the liability of a credible third party, rather than your own promise. As we said above, notes, cheques, debit cards, and related instruments issued by commercial banks have this feature. Returning to Venice, Mueller (1997) explains how deposit banking came to serve “a function comparable to that of checking accounts today; that is, it was not intended primarily for safekeeping or for earning interest but rather as a means of payment which facilitated the clearance of debts incurred in the process of doing business. In short, the current account constituted ‘bank money,’ money based on the banker’s promise to pay.”

Such a system can only work well if bankers are relatively credible, or trustworthy. Our theory says that the more patient or visible an agent is, or the more he has at stake, the more credible he becomes. The Rialto banks in medieval Venice offer

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22 As attested by Federico (1997), the first of these warehouses was funded by a group of entrepreneurs in Lyons in 1959. The Credit Lyonnais established its own warehouse in 1877 and was soon imitated by a series of Italian banks.

23 According to some, these early deposits did not actually circulate, in the sense that transferring funds from one account to another “generally required the presence at the bank of both payer and payee” (Kohn 1999). This is the argument for regarding the goldsmiths the first modern bankers. See also Quinn (2002). But even if they did not circulate, in this sense, the deposits of the earlier bankers clearly still facilitated payments. And Spufford (1988) documents that the Florentines were already using cheques in 1308.
evidence consistent with this idea: “Little capital was needed to institute a bank, perhaps only enough to convince the guarantors to pledge their limited backing and clients to deposit their money, for it was deposits rather than funds invested by partners which provided bankers with investable capital. In the final analysis, it was the visible pratimony of the banker – alone or as part of a fraternal compagnia – and his reputation as an operator on the marketplace in general which were placed on the balance to offset risk and win trust.” (Mueller 1997, p. 97). It is also interesting to point out that, although the direct evidence for this is scant, Venetian bankers seem to have been subject to occasional monitoring (as we assume in the theory): “In order to maintain ‘public faith,’ the Senate in 1467 reminded bankers of their obligation to show their account books to depositors upon request, for the sake of comparing records.” (Mueller 1997, p. 45). While it may have been prohibitively costly for depositors to continuously audit the books, one can imagine monitoring every so often. And if caught cheating, the punishment was indeed lifetime banishment from any banking activity in Venice, although apparently this happened rarely (as in the theory).24

We also mention that many bankers historically started as merchants, who almost by definition have a greater connection to the market than a typical individual. As Kohn (1999) describes it, the great banking families in Renaissance Italy and Southern Germany in the 16th century were originally merchants, who began lending their own capital and then started collecting deposits from other merchants, nobles, clerics, and small investors. They were not the wealthiest group; wealth then was concentrated in the hands of landowners, who controlled agriculture, forests, and mineral rights. But the merchants arguably had the most to lose from reneging on obligations. Thus,

24We think it is obvious that visibility and monitoring have always been crucial for good banking, but if one wants more evidence, going back to Roman times, Orsingher (1967) observes: “One of the most important techniques used by Roman bankers was the use of account books analogous to those which all citizens kept with scrupulous care. This account-book was called a Codex and was indispensable in drawing up contracts. .... A procedure peculiar to bankers deserves to be noted: the ‘editio rationum’ or production of accounts. Anyone running a bank could be compelled at a moment’s notice to produce his accounts for his clients’, or even for a third party’s, inspection.”
“because commerce involved the constant giving and receiving of credit, much of a merchant’s effort was devoted to ensuring that he could fulfill his own obligations and that others would fulfill theirs.” (Kohn 1999). Further evidence on the first bankers being individual who had a great connection to the market is given by Pressnell (1956) in its study of the origins of country banking in England during the Industrial Revolution. Almost all of the early country banks grew up as a by-product of some other main activity, usually some kind of manufacturing.

Also, returning again to Venice:

In the period from about 1330 to 1370, eight to ten bankers operated on the Rialto at a given time. They seem to have been relatively small operators on average... Around 1370, however, the situation changed [and] Venetian noble families began to dominate the marketplace. After the banking crisis of the 1370s and the War of Chioggia, the number of banchi di scritta operating at any given time on the Rialto dropped to about four, sometimes as few as three. These banks tended, therefore, to be larger and more important than before. Their organizational form was generally either that of the fraterna or that of the partnership, the latter often concluded between a citizen and a noble. (Mueller 1997, p. 82)

As in our model, there seem to have been interesting issues concerning the efficient number of bankers, and revolving around greater credibility or commitment and larger amounts of deposits per bank.

Finally, what does our theory say about banking panics, in general, and the recent financial crisis in particular? Gorton (2009) argues that the recent banking crisis is a wholesale panic, whereby some financial firms ran on others by not renewing sale and repurchase agreements. This resembles a retail panic in which the depositors withdraw rather than renewing demand deposits By analogy, depositors in the current crisis were firms that lent money in the repo market. The location of subprime risks among their counterparties was unknown. Depositors were confused about which
counterparties were really at risk and consequently ran all banks. While our framework is obviously far too rudimentary to grasp all the intricacies of the recent financial crisis, a perturbation to the model can highlight this one fundamental mechanism.

Thus, consider that the probability of being active each period $\gamma$ is subject to shocks. One can then imagine that the uncertainty surrounding these shocks could induce agents to not renew their deposits (or deposit less) to reestablish the banker’s incentives. What is more, our analysis implies that this is efficient. Such shocks may depend on the nature of the firm’s business – say, $\gamma$ could be affected by the housing market if that business is to originate mortgage loans, or it could also be affected by political events like war. More generally, whenever visibility goes down, in the sense that monitoring becomes more difficult, which we capture by a reduction in the probability $\pi$, the model predicts that credit will be hampered, as will all exchange that is facilitated by credit. But, again, this is efficient – mechanism design tells us that when $\pi$ becomes much lower, not only can the credit market cease up, it should do so. We are not necessarily advocating that there were no market failures associated with recent events. We are merely saying that it can be interesting to think about them through the lens of efficient mechanisms.

7 Conclusion

This paper studied banking using mechanism design. We began by describing an economic environment, with preferences, technologies, and certain frictions – including temporal separation, commitment issues, imperfect monitoring, and costly record keeping. We described the set of incentive-feasible and optimal allocations. We did not start with any prior assumptions about what banks are, who they are, or what they do. Rather, we looked at feasible or efficient allocations, and tried to interpret the outcomes in terms of arrangements that resemble banking. In the model, it is efficient for certain agents, chosen endogenously, to accept deposits, and these deposits help facilitate exchange. This can be part of an efficient arrangement even
if these agents do not have the best investment opportunities, as long as they are more trustworthy, which in the model means they are more patient, more visible, or have more to lose. Of course, other things equal, it is better if bankers have good investment opportunities. This activity resembles salient aspects of banking, both in modern and historical contexts. And it is essential: if we were to rule it out, the set of feasible allocations would be inferior. We discussed who would make a good banker, how many bankers should we have, and how to monitor them when it is costly.

We think the mechanism approach is useful for thinking about banking. We also think the underlying environment is interesting even if one does not take this approach. For example, one can impose a particular mechanism for exchange – perhaps bilateral bargaining, perhaps competitive markets, and so on – and look for equilibria. Are credit market equilibria efficient for these alternative pricing mechanisms? What is the nature of the equilibrium set? Does it involve interesting dynamics, like credit cycles? Can we learn more about the recent crisis? The environment is potentially a good one for this exercise because it captures interesting aspects of credit, like limited commitment, the use of collateral, and so on, in a very tractable way. It is tractable mainly because much of the interesting economic activity takes place across subperiods within a period, effectively making much of the analysis similar to that in a two-period model, yet is genuinely dynamic and makes good use of the infinite horizon (without this credit, like money, cannot get off the ground). The basic environments can also be easily generalized in many directions. For instance, it would not seem overly difficult to add uncertainty or private information. All of this is left to future research.
8 Appendix

8.1 Proof of Proposition 3

Since \( \gamma^b > \gamma^a \), it must be that \( U^1(x^b, y^b) \geq U^1(x^a, y^a) \). With deposits \( d \), and since there is one candidate banker in each group, the repayment constraint in group \( b \) becomes

\[ -\lambda^b \rho (y^b + d) + p^b \gamma^b \frac{\beta}{1-\beta} U^1(x^b, y^b) = 0. \]

Therefore, we obtain

\[ \frac{\partial p^b}{\partial d} = \frac{1 - \beta}{\beta} \frac{\lambda^b \rho}{\gamma^b U^1(x^b, y^b)}. \]

The repayment constraint in group \( a \) is

\[ -\lambda^a \rho (y^a - d) + p^a \gamma^a \frac{\beta}{1-\beta} U^2(x^a, y^a) = 0, \]

so that

\[ \frac{\partial p^a}{\partial d} = -\frac{1 - \beta}{\beta} \frac{\lambda^a \rho}{\gamma^a U^1(x^a, y^a)}. \]

Therefore, increasing deposits from group \( a \) to \( b \) reduces the overall monitoring cost \( p^a k^a + p^b k^b \) since

\[ \frac{\partial p^a}{\partial d} k^a + \frac{\partial p^b}{\partial d} k^b = \frac{1 - \beta}{\beta} \left( \frac{\lambda^b k^b \rho}{\gamma^b U^1(x^b, y^b)} - \frac{\lambda^a k^a \rho}{\gamma^a U^1(x^a, y^a)} \right) < 0, \]

where the inequality follows from \( U^1(x^a, y^a) \leq U^1(x^b, y^b) \), \( \gamma^a \leq \gamma^b \) and \( k^b \leq k^a \). Hence, from \( d = 0 \), only \( d > 0 \) can reduce total monitoring cost.

To prove the second part of the proposition, let \((\bar{x}^a, \bar{y}^a)\) solve \( \max_{x,y} W^a(x,y) \), subject to the participation constraint for \( 2^a \) only. If

\[ \bar{\pi} \equiv \frac{1 - \beta}{\beta} \frac{\lambda^b (y^b + \bar{y}^a)}{\gamma^b U^1(x^b, y^b)} \leq 1 \]

then it is optimal to set \( p^b = \bar{\pi}, d = \bar{y}^a \), and \( p^a = 0 \). \( \bar{\gamma} \) is then defined as

\[ \bar{\gamma} \equiv \frac{1 - \beta}{\beta} \frac{\lambda^b (y^b + \bar{y}^a)}{U^1(x^b, y^b)}. \]

8.2 Existence of Feasible Allocations (Section 5.2)

With \( d = t = 0 \), the participation and repayment constraints are

\[ u(y^i) - x^i \geq 0 \]
\[ -p^i k^i + (1 + \theta^i) (x^i - y^i) \geq 0 \]
\[ x^i - y^i \geq \delta^i y^i \]
where \( \delta^i = \lambda^i (1 - \beta) \). Let \( \pi^i_p \) and \( \pi^i_R \) be the monitoring probability \( p^i_0 \) such that the participation and repayment constraint bind respectively. The repayment constraint is satisfied iff \( p^i_0 \geq \pi^i_R \). The participation is satisfied iff \( p^i_0 \leq \pi^i_p \). Therefore, given an allocation \( x^i_2 \), \( p^i_0 \) exists iff \( \pi^i_R \leq \pi^i_p \). Replacing the expression for \( \pi^i_R \) and \( \pi^i_p \), we obtain

\[
\lambda^i k^i \left( \frac{1 - \beta}{\gamma^i \beta} \right) \leq \left( \frac{1 + \theta^i}{y^i} \right) (x^i - y^i)^2
\]

An allocation \( y^i \) is feasible if this condition holds. Since the planner seeks to minimize the monitoring cost for each allocation \( y^i \), he will set \( p^i_0 = \pi^i_R \) for any feasible allocation.

### 8.3 Rate Of Return Dominance: Example

To illustrate this point, consider again the case in which \( U^1 (x, y) = x - y \) and \( U^2 (\rho y, x) = u(\rho y) - x \). Also, let \( \gamma^a = \gamma^b \) and \( \lambda^a = \lambda^b = 1 \), and assume that the planner puts equal weights on types 1 and 2, \( \omega_1 = \omega_2 = \omega \). Also, assume \( \rho^a = \rho > 1 = \rho^b \). Absent any interaction between the two groups and given \( \omega_1 = \omega_2 \), the planner solves

\[
\max_{x^i, y^i} \frac{\gamma}{1 - \beta} \omega \left[ x^i + u(\rho^i y^i) - x^i \right] \tag{26}
\]

s.t.

\[
u(\rho^i y^i) - x^i \geq 0 \text{ and } x^i - y^i \geq \delta^i \rho^i y^i \tag{27}
\]

Notice that the objective function is independent of \( x^i \), while the LHS of the participation constraint for \( 1^i \) and the repayment constraint are both increasing in \( x^i \). Therefore, given \( y^i \), setting \( x^i = u(\rho^i y^i) \) maximizes the IF set for the planner. The problem then simplifies to

\[
\max_{y^i} u(\rho^i y^i) - y^i \tag{28}
\]

s.t.

\[
u(\rho^i y^i) - y^i \geq \delta^i \rho^i y^i \tag{29}
\]

Ignoring (29), the first best allocation \( y^{*i} \) solves \( \rho^i u^i(\rho^i y^{*i}) = 1 \). Hence, \( \rho > 1 \) implies \( y^{*a} > y^{*b} \). Notice that as the return increases, type 1 can reduce production and sustain a given consumption for agents 2. Define the \( \delta^i \) for which \( y^{*i} \) is feasible by \( \overline{\delta}^i \), so that \( \delta^i > \overline{\delta}^i \) implies the repayment constraint is violated at \( y^{*i} \). Also define
the allocation for which (29) holds with equality for a given \(\delta^i\) as \(y^i\), so that \(y^i > y^i\) implies that the repayment constraint is violated at \(\delta^i\).

Given \(\rho > 1\), we can have \(\delta^a < \delta^b\), so that \((x^{*,a}, y^{*,a})\) is feasible in group \(a\) but \((x^{*,b}, y^{*,b})\) is not feasible in group \(b\).\(^{25}\) Here we focus on a particular case, in which deposits in group \(b\) are PE. Below, we verify the following:

**Proposition 6** Deposits in group \(b\) are PE if \(\delta^a > \delta^b\), and either: \((a)\) \(\delta^b \leq \delta_b\) and \(\delta^a \rho > (\rho - 1) u' (\rho y^a)\) or \((b)\) \(\delta^b > \delta_b\) and \(\delta^a \rho > \delta^b + (\rho - 1) u' (\rho y^a)\).

The condition \(\delta^a > \delta^b\) implies that \(y^{*,a}\) is not IF in group \(a\), so that deposits potentially have a role. Then consider the situation in group \(b\). In the first case \((a)\), agents in group \(b\) do not have a commitment problem because \(\delta^b \leq \delta_b\), although they do have inferior storage technology. Therefore, making deposits in group \(b\) requires agents in group \(a\) to produce more to make up for the loss in return if they want to sustain a given level of consumption. There is a trade-off between commitment and returns. The condition \(\delta^a \rho > (\rho - 1) u' (\rho y^a)\) insures that the commitment issue is sufficiently severe, that is \(\delta^a\) is high enough, so that it is worthwhile for agents in group \(a\) to give up something on the rate of return and deposit resources in group \(b\). The right hand side measure the loss in utility in group \(a\) from forgone returns as deposits are increased, while the left hand side measure the decline in the gains from liquidation in group \(a\) when deposits are introduced.

The second case \((b)\) is similar, except that agents in group \(b\) have a binding repayment constraint when \(\delta^b > \delta_b\). Therefore, they need to be compensated for taking deposits, to prevent default. A transfer from group \(a\) does just that, but it comes on top of the additional production required from agents in group \(a\) to cover for the loss in return. Hence, in this case, deposits in group \(b\) are PE if \(\delta^a \rho > \delta^b + (\rho - 1) u' (\rho y^a)\), which is a stricter condition than case \((a)\). Finally, if the commitment problem in group \(a\) is very severe, notice that \(u' (\rho y^a)\) will be large. In this case, if the investment technology of group \(a\) improves, their commitment problem must be worse for deposits in group \(b\) to be PE.

\(^{25}\)In this case, even if we assumed \(\delta^b < \delta^a\), the repayment constraint could bind in sector \(b\) but not in sector \(a\). This would occur if, for example, \(\delta^a > \delta^a > \delta^b > \delta^b\). There are many interesting possibilities, some of which we analyze in the working paper (Mattesini et al. 2009).
The planner’s problem with no interaction between groups is given by (28). The first best solution is given by \( y_i^{*i} \) solving \( \rho' u'(\rho y_i^{*i}) = 1 \). Denote by \( y_i^* \), the level of \( y_i^{*i} \) that satisfies the repayment constraint (29) as an equality. Define \( \delta_i^* \) by \( [u(\rho' y_i^{*i}) - y_i^{*i}] / (\rho' y_i^{*i}) = \delta_i^* \) as the level of market connection below which the repayment constraint binds in group \( i \). These next two claims establish Proposition 5.

**Claim 1** Deposits in group \( b \) are PE if

\[
\delta^a > \delta^b, \quad \delta^b \leq \delta^b \quad \text{and} \quad \delta^a \rho > (\rho - 1) u'(\rho y^a) .
\]

**Proof.** Given a level of consumption for agents \( 2^a, x_2^a \) and \( d \), agents \( 1^a \) have to produce \( y^a \) such that \( x_2^a = (y^a - d) \rho + d \). The repayment constraint is

\[
u ((y^a - d) \rho + d) - \frac{y^a}{\rho} \geq \delta^a \rho (y^a - d) . \quad (30)
\]

To show deposits are PE in group \( b \), we show that increasing \( d \) relaxes the repayment constraint in group \( a \). Therefore it must be that at the allocation \( y^a \),

\[
(1 - \rho) u' ((y^a - d) \rho + d) + \delta^a \rho > 0 \\
\delta^a \rho > (\rho - 1) u' ((y^a - d) \rho + d)
\]

Hence deposits in group \( b \) are essential at the allocation \( y^a \) iff

\[
\delta^a \rho > (\rho - 1) u'(\rho y^a)
\]

**Claim 2** Deposits in group \( b \) are PE if

\[
\delta^a > \delta^b, \quad \delta^b > \delta^b \quad \text{and} \quad \delta^a \rho \geq \delta^b + (\rho - 1) u'(\rho y^a) .
\]

**Proof.** When \( \delta^b > \delta^b \), the solution to (28) in group \( b \) is \( y^b \). Deposits are incentive compatible only if agents \( 1^a \) make a transfer \( \tau \) to agents \( 1^b \). The repayment constraint in group \( b \) with transfer \( \tau \) and deposits \( d \) evaluated at \( y^b \) is \( u(y^b) - y^b + \tau \geq \delta^b (y^b + d) \). By definition, \( u(y^b) - y^b = \delta^b y^b \) and the minimum transfer \( \tau \) that keeps the constraint satisfied is \( \tau = \delta^b d \). The repayment constraint with transfers in group \( a \) is

\[
u ((y^a - d) \rho + d) - \frac{y^a}{\rho} - \tau \geq \delta^a \rho (y^a - d) . \quad (31)
\]
Substituting $\tau = \delta^b d$, the repayment constraint in group $a$ gives

$$u \left( (y^a - d) \rho + d \right) - \frac{y^a}{\rho} - \delta^a \rho y^a + \left( \delta^a \rho - \delta^b \right) d \geq 0,$$

so the repayment constraint is relaxed whenever

$$\delta^a \rho - \delta^b \geq (\rho - 1) u' \left( (y^a - d) \rho + d \right)$$

and evaluating at $y^a_2$,

$$\delta^a \rho - \delta^b \geq (\rho - 1) u' \left( \rho y^a_2 \right).$$

This completes the proof. ■
References


of 2007," mimeo.


